USING LIGA BASED MICROFABRICATION TO IMPROVE OVERALL HEAT TRANSFER EFFICIENCY OF PRESSURIZED WATER REACTOR: I. Effects of Different Micro Pattern on Overall Heat Transfer

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Introduction

Pressurized water reactor (PWR) is widely used device to generate high temperature and pressure steam for variety of applications. This study is to develop the innovative technology and knowledge for economic exploration of novel microfabrication techniques (specifically LIGA based techniques) for producing micromechanical structures using complex engineered materials that can be successfully utilized PWR and hence could contribute to enhancement of its heat transfer properties, operating efficiency and reduction of the overall payload.

There are mainly three factors that will significantly affect PWR overall heat transfer and operating efficiency, which can be significantly alternated by microstructures, micro-patterns made from LIGA technique: (1) heat transfer surface area [1], (2) the near surface fluidic flowing pattern and resulted boundary layer thickness [2], (3) the most important one, boiling behavior or vapor bubbling formation processes [3].

The current work is focused on the effects of poles density change on overall heat transfer. Different kind of micropatterns have been manufactured and tested. Thermal properties such as normalized diffusivity values, heating speeds have been measured to evaluate the overall heat transfer efficiency of each micropattern.

Experimental

Sample Fabrication

Disk shaped samples with in-line micro-pin fins have been fabricated from SU-8 photoresist (Fig. 1). The samples were made in a two-layer process. The bottom layers are 12.6mm diameter discs with height value about 400µm. The top layers are 100 × 100 µm square posts with height around 250µm at different spacing values of 50, 100, 200, 300, 400, 500, 600, and 700 µms, respectively. In order to contain the oil on the samples, a circular dam of 500µm width is designed at the edge of each sample (Fig. 1).

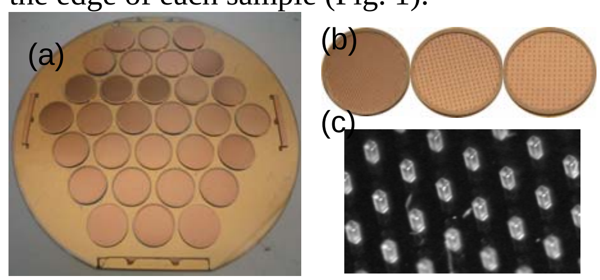

Figure 1. Samples made from SU-8, (a) samples as made;(b) dry-released samples; and (c) a close-up view.

Apparatus and Measurements

A NETZSCH LFA 447 Nanoflash diffusivity instrument has been used to measure the overall diffusivity and heating speed of each sample.

In order to enhance the absorption of flash energy and the emission of IR radiation to the detector, and reduce the reflection from the faces, a layer of approximately 5 µm graphite was applied for all testing samples. Flash power, pulse width and filter were kept constant for all measurements. Five Xenon flash shots were performed at each testing point of 50°C, 100°C and 150°C. Then the temperature rising data were collected. Cowan plus pulse correction analysis was used to calculate the thermal diffusivity.

The thermal diffusivity and heating up speed tests were performed with samples both under atmosphere and filled with fixed amount mixture of graphite nanoparticles and Canola® oil (1:150 w/w). When filled with oil, the oil surface will cove the whole sample top surface.

Results and Discussion

The overall thermal diffusivity of samples filled posts' spacing with air and oil at 100°C are shown in Fig.2. The overall thermal diffusivity values were calculated with an overall thickness, which is the sum of bottom layer thickness and post height. It is expected that air filled samples have higher diffusivity values than that filled with oil because air diffusivity (~37mm^2/s) is much higher comparing with oil (~0.1 mm^2/s). For air filled samples, the effects of spacing on diffusivity leveled off after the post spacing value is larger than 200µm. For oil filled samples, the values started to drop after the post spacing is larger than 400 µm.

Heating rate measurements were used to evaluate the heat transfer efficiency of different spaced micro poles. Samples were filled the space with oil mix and the temperature change as the function of time is monitored after fixed amount of heat is applied at the bottom of the samples (Fig.3). For current pattern design and materials, the heating rate picks at post spacing around 500µm and drops when the spacing value becomes larger. The highest heating rate at 500µm spacing implies that it has the highest total heat transfer efficiency under tested condition. The same tests were performed on air filled samples for quality control purpose and there is no pick on the heating rate values because the detector was calibrated in the ambient air.

Conclusions

The overall heat transfer efficiency of micro-post patterned structures is evaluated by using thermal diffusivity and heating up rate measurements. It is clear that different micro patterns will affect the overall heat transfer property of the solid/liquid interface under static condition. For current materials combination and testing condition, sample with a spacing value of 500 µm has the highest overall heat transfer efficiency. This study results suggest that for given solid/liquid system, there will be an optimized microstructure pattern that will result highest overall heat transfer efficiency.

Acknowledgements

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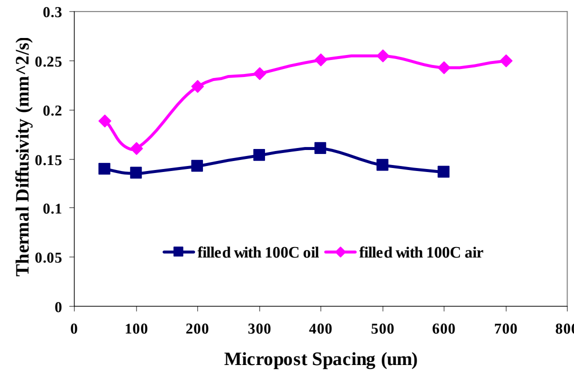

Figure 2. The overall thermal diffusivity values as the function of micro-post spacing.

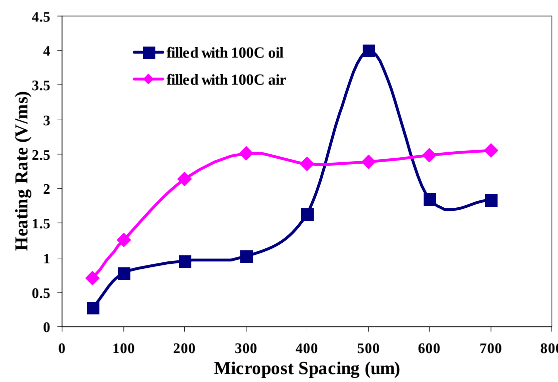

Figure 3. The measured sample heating rate values as the function of the micro-post spacing distance.

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